Interactive Electronic Whiteboards in the Medical Classroom

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Most research on computer-assisted instruction has concentrated on developing systems to be used outside the teaching environment to supplement or complement in-class teaching. We believe that interactive large-screen computers can be used effectively in the classroom *as electronic whiteboards to more effectively teach select medical school courses. We describe our experience with one such device, the Xerox LiveBoard™, to teach a course on computer-assisted clinical decision analysis to a group of first-year medical students.*

INTRODUCTION

Since the early 1960s, researchers have envisioned the promise of computer-assisted instruction (CAI) and have developed many systems for use by medical students and other health professionals [13]. Development and implementation of CAI systems is a major focus of medical school curriculum committees in both the United States and abroad [8, 15]. However, the instructional media used in the medical school classroom generally remain limited to blackboards, 35mm slides, and overhead transparencies, supplemented by the occasional use of video. This range is expanding with the advent of new computer hardware and broadband communications [14].

For example, researchers in the computer-supported cooperative work (CSCW) community are developing interactive large-screen computers for use in collaborative work environments. Although the primary intent of these devices is to support group meetings, presentations, and remote collaboration, we believe that such devices can also be used effectively as electronic whiteboards for teaching purposes [5,8].

Most CAI research has focused on developing systems to supplement or complement the role of teachers, either through out-of-class tutorials or, less often, through in-class computer laboratories which reduce the teachers' role to the management of instructional material [2]. We have sought instead to augment the practices of educators, aiding, in this case, classroom interaction with students and information. Apart from one very early endeavor [1], little research has been done on taking the computer into the medical classroom for use in teaching. In this paper, we describe our experience using the Xerox LiveBoard™ to teach a course on clinical decision analysis to a group of first-year medical students.

THE XEROX LIVEBOARD

The LiveBoard is a large-screen pen-based computer developed by researchers at Xerox Corporation's Palo Alto Research Center (Figure 1) [5]. In its standard configuration, the LiveBoard is powered by an Intel 486-based computer. The image is produced by projecting a liquid crystal display (LCD) onto a 4-ft by 3-ft rear-projection screen with a standard VGA display. Input to the LiveBoard is through wireless pens, and through the keyboard and mouse. Pens can be used

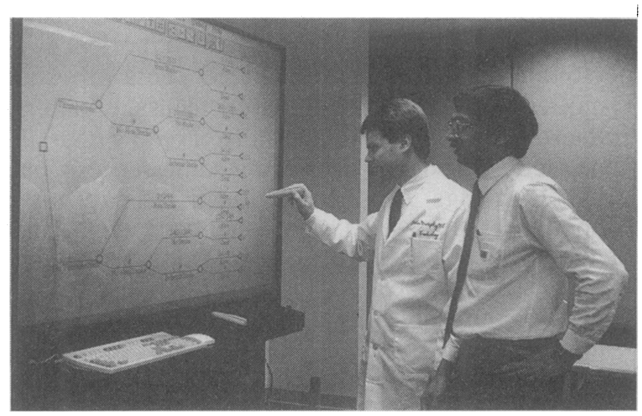

Figure 1: View of the LiveBoard being used by two instructors in a course on clinical decision analysis to create a decision tree.

both by touching their tips to the screen and from distances of several feet from the screen.

The standard LiveBoard software configuration includes Microsoft Windows® and Microsoft Pen Extensions for Windows™. The LiveBoard is capable of running all software compatible with Microsoft Windows. The Pen Extensions provide support for handwritten character recognition and gesture-based interaction with software. The LiveBoard also features multimedia support through an audio system as well as full-motion video.

A key advantage of the LiveBoard is the size of its display, which enables collaborative work at a common location by creating a large, shared workspace for group interaction. In addition, multiple LiveBoards in different locations can be connected using existing data communication technologies to permit simultaneous remote collaboration. Using the time-space taxonomy of groupware systems, the LiveBoard supports "same time/same place" as well as "same time/different place" interaction [4]. The Washington University School of Medicine, through the Advanced Technology Group (ATG) in the School of Medicine Library, is studying the use of LiveBoard technology in digital libraries, computer-supported collaborative work, and education [11].

CLINICAL DECISION ANALYSIS AND THE LIVEBOARD

The curriculum for first-year medical students at Washington University School of Medicine includes a six-session elective mini course on clinical decision analysis. Effective teaching of clinical decision analysis requires the use of software to interactively construct decision trees, elicit probabilities and utilities, calculate expected utilities in real-time, and perform one-way and two-way sensitivity analyses [16]. It also requires the presentation and annotation of such didactic material such as diagrams, images, and text.

The LiveBoard is a useful technology to combine these activities and media, and was a logical choice as the teaching medium for the clinical decision analysis mini course. Wireless pens can be used to "write" on the LiveBoard facilitating its use as a whiteboard. Slides made in Microsoft Powerpoint® can be displayed and annotated using the pens. Spreadsheets made in Microsoft Excel® can be displayed and used for real-time interactive calculations.

TIDAL—TEAM INTERACTIVE DECISION ANALYSIS IN THE LARGE-SCREEN ENVIRONMENT

We surveyed existing software packages such as DATA™ (TreeAge Software, Inc., Boston, MA), Decision Maker© (Division of Clinical Decision Making, New England Medical Center, Boston, MA), and DPL™ (Applied Decision Analysis, Inc., Menlo Park, CA). However, none of these are easily modifiable to support gesture-based input which is an essential form of pen interaction, and to create hypermedia links to electronic information sources. Hence, we developed TIDAL—Team Interactive Decision Analysis in the Large-screen environment.

TIDAL is a "groupware" application for team-based decision analysis. In its current version, TIDAL supports the interactive construction and manipulation of decision trees using pen-based gestures, menus, and keyboard commands. A tree is constructed by creating the structure of the tree, labelling the nodes and arcs, assigning probabilities to the arcs emanating from chance nodes, and assigning utilities to the outcome nodes (Figure 2). Analysis in TIDAL consists of real-time calculation of expected utilities, and rapid one-way and two-way sensitivity analyses.

TIDAL uses a generalized multimodal graphical editor to implement a direct manipulation user interface. The system was written in Microsoft Visual C++ and supports OLE 2.0 (Object Linking and Embedding). At its core, the TIDAL system supports generalized computations over graph-based formalisms. In addition to decision analysis, the system will eventually support compartment modelling.

MINI COURSE—COMPUTER-ASSISTED CLINICAL DECISION ANALYSIS

The goal of the mini course was to teach students an analytic methodology to solve difficult clinical problems and arrive at informed medical decisions. The analytic methodology—clinical decision analysis—combines pathophysiology, diagnostic test interpretation, treatment efficacy, patient preferences, and cost-effectiveness. Fourteen students signed up for the course. The following topics were covered in six sessions:

1. Diagnostic test interpretation [7]
2. Decision tree construction [10, 16 pp. 147–61]
3. Utility assessment for health outcomes [17]
4. Biases in utility assessment
5. Probabilities and sensitivity analysis [18]

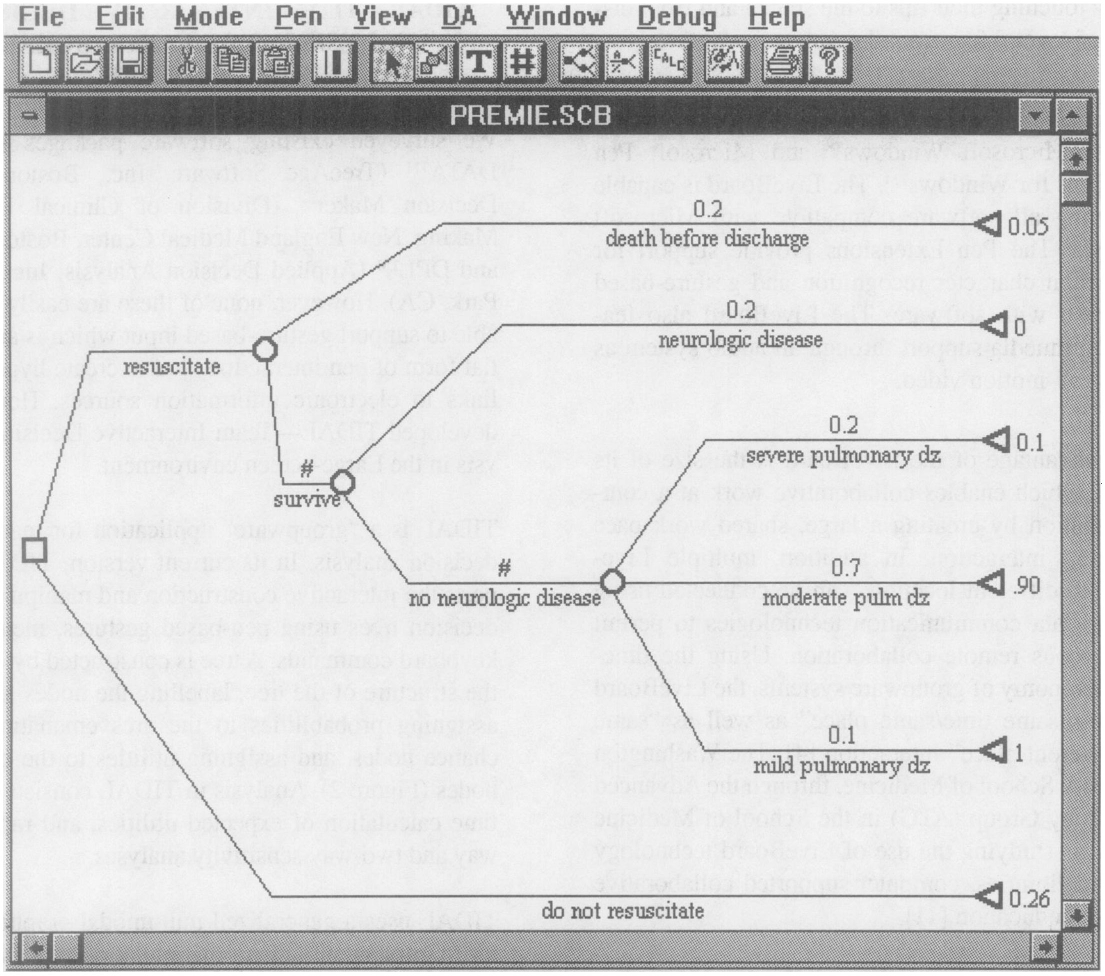

Figure 2: A screen view of TIDAL. This example is a decision tree used for analyzing the decision to resuscitate a premature baby.

6. Cost-effectiveness analysis [3].

The LiveBoard and Powerpoint slides were used in teaching all sessions. Additionally, we used Excel in the first session and TIDAL in the second through sixth sessions. For the third session on utility assessment, we used "Gambler" from the New England Medical Center in Boston [6]. Unlike traditional media, we could simultaneously execute and easily switch between all these applications. All sessions were videotaped for retrospective review.

Several clinical examples were used to illustrate the concepts being taught in class. For diagnostic test interpretation, the examples included: anti-nuclear antibody test to diagnose systematic lupus erythematosus; magnetic resonance imaging or auditory brain stem response to detect an acoustic neuroma in unilateral sensorineural hearing loss; and screening for prostate and breast cancers. Excel macros were written to compute positive and negative predictive values given the sensitivity and specificity of a diagnostic test and prior probability of the disease.

For the construction and evaluation of decision trees, elicitation of probabilities and utilities, and sensitivity analyses, the decision scenarios included: administering thrombolytic therapy to acute myocardial infarction patients with elevated blood pressure [12]; activity recommendations for athletes at risk for sudden cardiac death; resuscitation of an extremely premature infant (Figure 2); and performing surgery for a suspicious pancreatic biopsy. TIDAL was used to demonstrate the features of a decision tree such as decision nodes, chance nodes, and outcome nodes, and other aspects of decision analysis such as calculating expected utilities, and performing one- and two-way sensitivity analyses. The interactive nature of TIDAL allowed us to construct the decision trees in class with active participation from all the students. We were also able to demonstrate expected utility calculation and sensitivity analysis in real-time. This would not have been possible with the use of traditional 35mm slides, overhead transparencies, or a blackboard where it would have been necessary to create decision trees and perform analyses before class. Using TIDAL and the LiveBoard also taught students the necessity of collaboration and iteration in medical decision making and made the sessions more interesting.

For the assessment of utilities, we used the health outcomes in the following decision scenarios: administration or withholding of thrombolytic therapy for acute myocardial infarction patients; surgery or radiation therapy for prostate cancer; and toe or below knee amputation in diabetic patient. All four utility elicitation methods present in Gambler were taught, and students worked on the LiveBoard to perform the utility assessment for the last two examples.

STUDENT EVALUATION

We conducted two course evaluations to assess the views of the students on the use of the LiveBoard and TIDAL for teaching clinical decision analysis. An interim course evaluation was given at the end of the fourth session, and a final course evaluation at the end of the sixth session.

In the interim course evaluation, most students (83%) responded that the LiveBoard was better than the conventional teaching methods that they had experienced previously. Most students (92%) found TIDAL to significantly enhance their understanding of decision trees, and all students (100%) found Gambler to improve their understanding of utility assessment.

In the final evaluation, students were asked to rate features of the LiveBoard which we felt were important for its suitability as a teaching device. Table 1 shows the averaged responses of the students. Most students (91%) wanted to have TIDAL made available to them or installed on computers in the Library's media center.

In both evaluations, students were asked to write in comments on aspects of the LiveBoard or TIDAL that they liked or disliked. Features that most students liked were the real-time calculation of expected utilities enabling them to see immediately the results of a different set of probabilities or utilities in the same decision tree. They also liked the real-time calculation and display of sensitivity analyses which summarized the decision over a range of probabilities or utilities. Many students found the LiveBoard to be novel and different, and found the course to be more interesting due to the increased interactivity provided by this new technology. A few students added that the LiveBoard would be an excellent teaching device in courses where the number of students is small. When asked to identify other courses where they would like to use the LiveBoard, many students suggested medical genetics. Some students wanted to use its multimedia capability to visualize simulations of common physiologic processes or to interactively explore the quantitative relationships among the different components of the physiologic system.

Table 1: Average responses of the students on the various features of the LiveBoard. The following scale was used for the responses to the evaluation:
1: Very helpful; 3: Somewhat helpful; 5: Not helpful

LiveBoard / TIDAL features	Avg. rating
Drawing decision trees during lectures	2.0
Entering probabilities and utilities interactively during lectures	2.0
Calculating expected utilities instantaneously	1.4
Displaying sensitivity analyses graphs	1.7
Using Gambler for utility assessment	2.0
Handwritten character recognition	3.5
Switching instantaneously between slides and course software	2.4
Readability and quality of the display	2.2
Lack of simultaneous use of a blackboard/ chalkboard	1.9

Students were critical of handwritten character recognition and felt that it added unnecessary time to the process due to the number of mistakes it made. Students also criticized glare from the screen surface and the low resolution which occasionally made it difficult to read the contents on the screen.

FUTURE WORK

Given the success of the course and the positive feedback from the students on the LiveBoard and TIDAL, we plan to use it again next year for teaching this mini course. We want to design a system whereby students in the class can follow the instruction on their own portable computers, thus allowing them better interactivity with the course software and ready access to the course material outside class hours.

We are planning to extend TIDAL to incorporate hypermedia links to electronic sources of information such as MEDLINE to point directly to objective sources of probabilities in the literature. We will also extend TIDAL to support group decision making by collaborators located in different places.

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